Product Engineering and Design Thinking
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Module - 06
DFM, Rapid Prototyping and Affordability Engineering
Lecture - 29
Rapid: Digital Prototyping

Welcome back to the NPTEL course on Product Engineering and Design Thinking. We are discussing today the Rapid Digital Prototyping. Normally or usually as you hear rapid prototyping, perhaps you have heard because that is a very popular term these days that people normally think that rapid prototyping is only concerned with the 3D printing machine or a rapid prototyping machine. But actually, it has got two parts.

One is the digital part and then there is a physical conversion into the product based on the correct digital model. So, here when I am delineating the word correct, then there is a connotation which we will discuss in course of time. So, the rapid prototyping which is done through additive manufacturing process commonly, of course, there are also hybrid manufacturing where both additive and subtractive principles are used.

But generally, the additive manufacturing is the commonplace. So, a people normally think that is the a only rapid prototyping activity. But behind that the lot of digital activities that go on that is most vital and in this session, we will address that part and the additive manufacturing based rapid prototyping will be dealt with in another session.

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Here I would like to go first to the concepts covered in this session. We as I have said we would talk about the digital part of it or in short it is called digital prototyping or virtual prototyping for rapidity. Obviously, the rapidity its need also is you know discussed in this context.

But here I just I would like to point out that in the literature and commonly people call it digital prototyping or virtual prototyping. But in very strict sense in some cases virtual prototyping means that where the augmented reality or virtual reality procedures will be used. So, that specifically is called virtual prototyping, but for our case in general as the literature presents it in that way and as in the professional world that is also called that way, we would use the terms interchangeably either digital or virtual prototyping.

So, in this context we will discuss various trends and softwares, various software like say PLM, CADD, CADD that is Computer Aided Design and Drafting we will discuss. And we will discuss the digital prototyping process and its advantages. We will discuss one thing that how the 3D experience in digital environment is realized.

And in this context, I would like to also point out that I got certain material from our associate who has shared this with us and that is Solis India and they actually have shared the digital systems platform details, some details which will be adequate for this session, that we will discuss where various features of the digital prototyping, digital manufacturing has been dealt with.

This is kind of a physical, cyber physical system and therefore, comes in the domain of industry 4 point o it can be tagged very well with industry 4.0 as a cyber physical system. Because the cyber part of is done digitally mostly and then the physical part is performed through this rapid prototyping machine be it additive or be it additive comes subtractive etcetera.

Now, with that we will go to certain application areas like say or say certain attribute areas like say ergonomics is an area which is important for the designers. Like say for example, for automotive ergonomics is important say for assistive technology, say for designing a wheelchair that ergonomics is important, aspect that we will discuss.

For a complex system say which includes multi-disciplinary approaches which is a mechatronic system. Say for example, a robotic system where the simulation is done through this digital systems and that we will discuss and how it helps in prototyping that also we will elaborate.

Finally, once the digital part is complete then for physical prototyping one has to actually translate into physical component. Because physical component often is necessary as certain aspects which are not. So, well testable through digital model like say for example, the ergonomic comfort or advantages for that real model would be necessary.

In this context the translation happens through CAM or computer aided manufacturing. Of course, one thing which goes into the simulation as I said which is computer-aided engineering that also will be discussed here. The issue is that the solution for CAM is a digital approach and many prototypes which earlier used to be done only through physical models now can be done with using virtual prototyping where real world experience virtually could be obtained through the augmented reality or virtual reality procedures and the technology.

So, we will touch on that also and finally, we would say that we are presenting that platform where it is interestingly also is a cloud based that gives the flexibility of working between a student and or teacher or between two colleagues elsewhere. So, on it so team working is possible through clouds. So, with this concept covered area we will move on to individual aspects and then we will talk about the digital prototyping to start with what is it.

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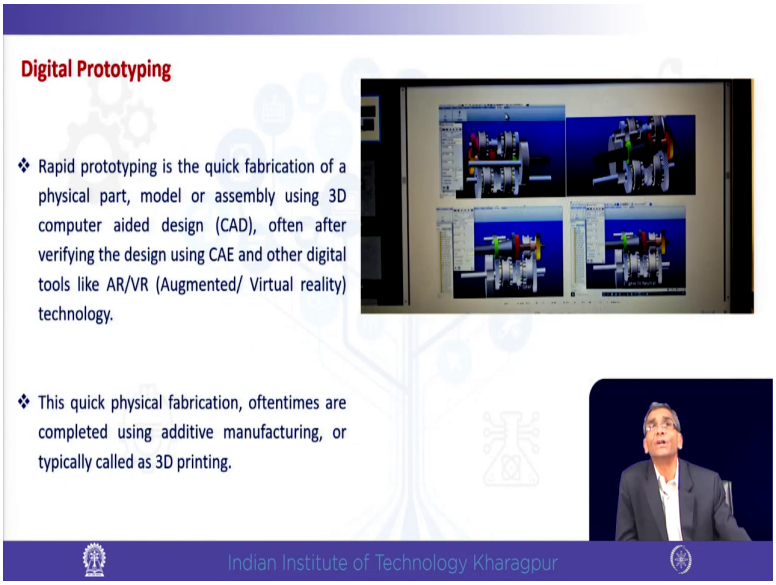

So, rapid prototyping as we said that it is a quick fabrication of physical part ultimately or assembly using a 3D computer-aided design CAD often after doing the performing the CAE that is Computer Aided Engineering or simulation is called. Like say when we want to test whether that component will be here will be able to bear the load or the or what is the force coming on that load component or what is the stress etcetera. So, those things we can test before actually we make it.

Because that practically can be done without investing into any physical part and it is very speedy, fast and least very inexpensive that way because no material is to be procured or no manufacturing process to be carried on this. So, and as I have said also with CAE the AR, VR technology also comes on it and there are other softwares also for say multi-body dynamics and other things are there.

So, students will actually be picking up things one after another as one first gets into the most important software or application like say CAD or CAE, these are two very important software perhaps you already know or have some exposure maybe you can you are need to brush up a bit here or there maybe for a week or two's time for the CAD, be it auto CAD, be it solid works or solid edge or catia or anything are similarly for the simulation.

It may be Simulia or it may be ANSYS, ANSYS which is a very popular software in this simulation where this testing are possible virtually or digitally. So, those are the things may be learned and those who have learnt already the some CAD software for them it is not difficult at all and there are tutorials available on YouTube and other places and so one can pick that up quite easily.

And within a very reasonable time period may be a month or two depending on how one is devoting time and taking interest. So, finally, after this digital process is complete then the physical process with the machines are performed for or commonly which is called 3D printing.

Here again I just repeat it is not only additive manufacturing there are equipment which are modern very sophisticated where additive subtractive can be done in one machine. Because that gives the optimum usage of time and naturally it becomes even faster where the removal is economical than adding. So, those are the kind of things that we will do.

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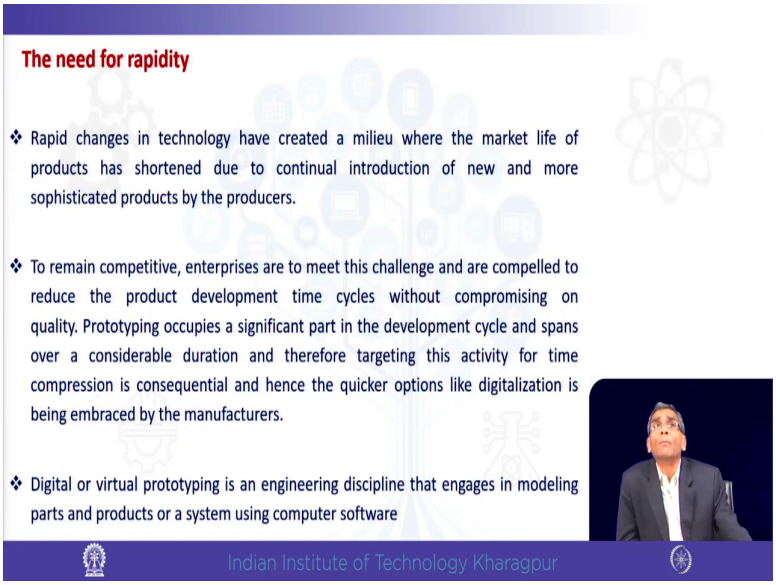

But here we first would deal with the need why are we discussing this what is the why rapidity is so needed. Because the world is changing very fast people's test choices preferences are changing very fast and technologies are being developed every day new technologies are coming up.

So, with these kind of things in this milieu the market life of a product is getting shortened or reduced that which earlier if one motor car would last for 20 years people would live with that

car even his progeny would be using the car, but gone a those days now every 3, 4, 5 years people change the car model car etcetera.

So, that trend is different now. And to do that the companies are to come out with new products be it on the high end or be it on the low end whatever it is depending on the target segment that they are targeting, but that is what it is, but new products are to come. So, now the new products are to come quickly. Because the competition is such that everyone is intending to introduce their products quickly and those who can introduce such product quickly would gain the market share.

So, that is where the competition is and that is where the technology challenge is. And hence modern engineers would be expected or required to respond to that challenge. And that is where we believe that this capability should be developed and can be developed using this kind of practices which we are discussing during this session.

So, while we are trying to compress the time reduce the time, we it is that it is to be remember that the quality cannot be compromised. So, hence if that is the thing then quickening the process is done preferably and practically through digitalization and which is being embraced by the manufacturers from that reason. It is an engineering digital and virtual prototyping is an engineering discipline that engages in modeling of parts and products or system using computer software that I said in the beginning also.

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And we will talk about those. For example, PLM or Product Lifecycle Management is the method of managing the entire lifecycle of products. Starting with the initial concept development through the physical development or the design development and manufacturing. Manufacturing means this prototype and manufacturing to improve the product. So, that is the task. So, the CAD use of CAD is indispensable there.

Finally, the CAD the drafting is important once it is in the software zone that we can experience what is happening there visually digitally, but then a for communication to the factory floor to the manufacturer it is necessary that the hard copy would be necessary. And that hard copy therefore, would be printed through the drafting capability.

Industries and most engineering disciplines use CAD for that purpose to enhance their productivity reduce cost and most significantly shorten the product engineering time.

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So, here in continuation with this we have kept this slide, but we have already discussed this, but you can study this later on. Also, when you get time later, but this is it enables the engineers to explore design options determine various parameters, decide part tolerances. Through this digital CAD process and digital or virtual prototypes or digital mock-ups what you call can be created through this.

And therefore, it is focused on the digital prototyping area where starting from the sketching, the analyzing, designing, manufacturing it is drawing major attention. And finally, the hardware based modeling is done as I said it will be discussed in a different resource.

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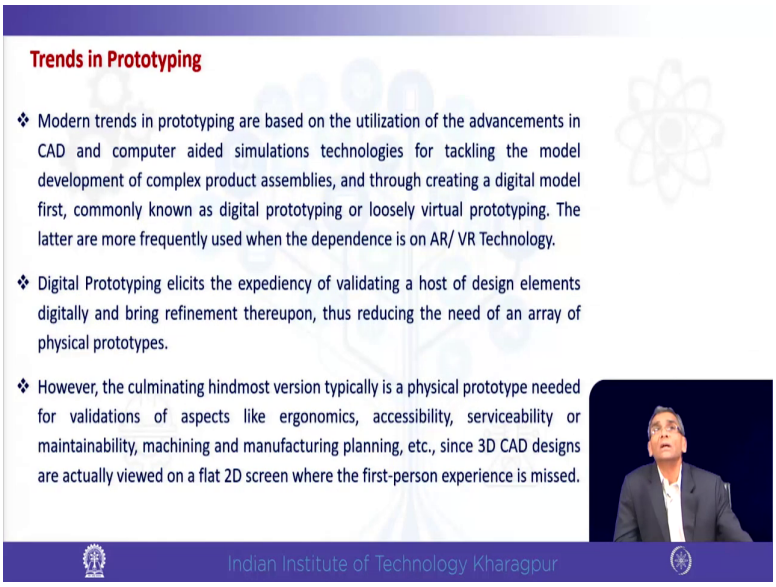

So, transient prototyping I have already discussed this part that is the CAD or AR, VR technology that is coming up, that has come up in fact, it is an emerging technology being adopted by industries, particularly to tackle the model development complex products, complex product assemblies say mechatronic assemblies where multi-disciplinary approaches are involved, mechanical, electrical, electronics, software, computer science or information technology or other and also material science. These are the you know components coming in.

So, finally, I have I mean the culmination finally, happens after this into the hardware model through the rapid prototyping. This here in the software after all we seen in flat screen as a 2D screen, but the even if it is a 3D CAD, we see it in 2D screen. So, the first experiences missed for which the hardware model is often necessary.

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Virtual prototyping is where AR, VR is used. This is effected using digital devices like say VR goggles that help with a real scale experience for all concerned. Maybe you have already seen some of this or you have gone to some place where you could where a such a goggles and goggles and you could see how one can have experience or you can now do it from some place. It is quick and cost saving in prototyping as I just said because you can experience how the solid model would look like and behave like.

So, that is very helpful. And it is a it is very significant therefore, for innovations and many technologies along this path has been developed to support this and many are coming up to ease out the complexity in prototype design development etcetera and manufacturing of the same. So, the virtual prototyping is coming here in prototyping domain.

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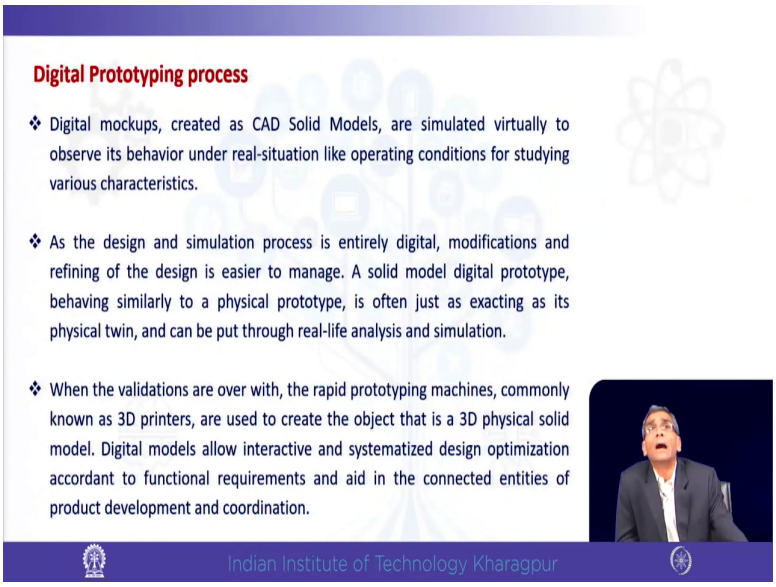

So, now we will go to the digital prototyping process. The design and simulation process mainly as I said the design that is CAD and then simulation that is CAE Computer Aided Engineering. Broadly when people say in a CAD environment, they mean both the CAD and CAE, but when we are discussing it technologically, technically we should differentiate and talk about it.

A solid model digital prototype behaving similarly to a physical prototype is often just an exacting as its physical twin and can be put through real life analysis and simulation. So, through simulation we can examine, test check those parameters or attributes, load bearing capacity, its extent of deformations, possibilities etcetera. Or say it is a shape, how the shape is changing and all that.

When the validations are over with then the rapid prototyping machines commonly again I would say here also to complete the process in physical form, then the rapid prototyping machine is used for building it physically. But before that these two areas I would reemphasize that a person if he or she learns CAD and CAE the opportunity is actually immense because there are really dearth of good designers.

Apart from the fact that there are career choices even those who apart from the industry who would like to go for higher education, they are apart from the commonly called MDes, there are MDes that Master of Designs there this knowledge would be very helpful and admission would be convenient.

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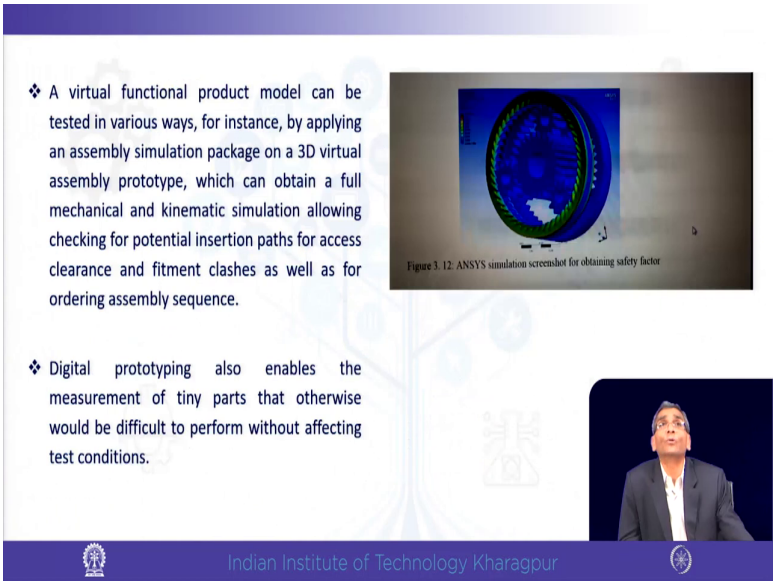

So, anyhow so that we all know and hence we will progress to the virtual functional product model can be tested in various ways, that is what the CAE aspect of it. So, the simulation

package which here as I said either through ANSYS or any other software like say Simulia or any Simon software etcetera. They are there to help us out in this.

If apart is very very small and if it is to be checked and tested and measured it and often cannot be done without affecting the test conditions. But digitally there is no problem one can very well see how a small micro tiny part can fit into give the functionality. That digitally is quite possible and that is the great advantage.

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So, although we have discussed the summary points in various places, but here is a short summary of advantage of digital prototyping. So, it is a practically reiteration of what we have said less time for testing as the entire process is carried out virtually or digitally. Prior to building the product the aid through analysis of the motion behavior of complex system can be obtained.

Supports exploring multiple design options quickly, digital mockups are usable to test a wide range of component parts or entire complex product, visual mockups are used to obtain customer feedback early on. This is one very interesting area. Because with the you know a digital mockup, we often you will see that the presenter is going with the laptop to show that ok, this is how it will work, how it will move, how it will act, how it will function and all.

So, that is a low fidelity prototype. It is not a physical model though, but it is good enough to for the user to understand or the stakeholders to understand how it will work and how it will function. Often the MVP or Minimum Viable Product, the minimum viable product is where only the core functionalities are to be tested with the user or customer.

So, there it is very very useful in digital form as well. Some industrial applications of digital prototype include ergonomic or engineering design of automobiles, in aircrafts equipment, medical equipment, power plant machinery, ship building, defense it is practically everywhere. The application of digital prototyping is now everywhere, every industry need it name it and they are there.

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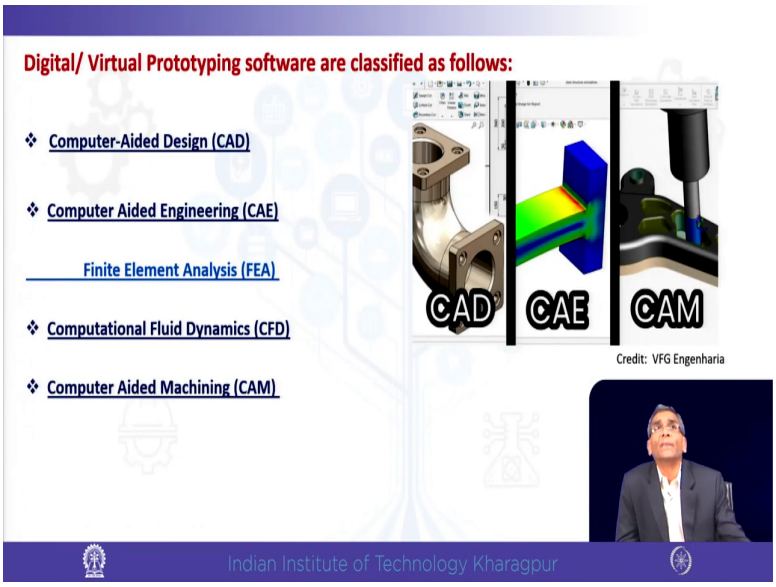

These are possibly already taught in your course, but or you can learn it from any other standard sources even through internet apart from books and all. But in short, I would present that the as I said the CAD, CAE, CAE works on the finite element analysis mode, if it was in the course fine or else you can just understand.

And understand what FEA is because that is a that is the base or the technology or the what do I say the principle on which this is a mathematical equations is converted to design or design is converted to method models and solved.

So, where FEA comes in. Similarly, computational fluid dynamics in say in heat exchanger design or where you know thermal cooling is happening there all these kind of applications, CFD can be used. And finally, Computer Aided Manufacturing which actually dictates the

machine any machine CNC machine mainly where is the controller that from that CAD model it will build.

I have prepared certain slides for your consumptions later because you just will go through as a study mat. So, I have kept in there. And because those are in simple terms because I am duty bound to at least a give out the outlines of each. So, I have presented, but I know you already are exposed to this.

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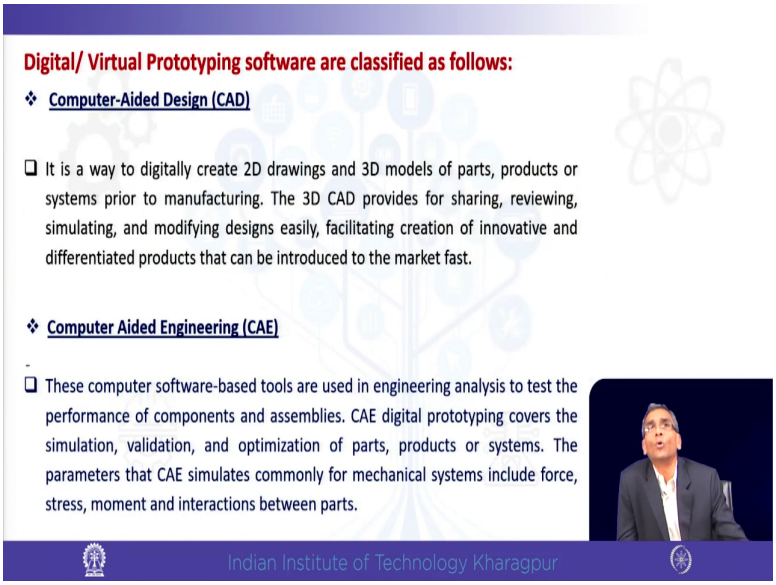

So, but briefly I have presented. So, that whenever you later on would like to revise you can just go to this slides and you will see it is a way of digitally create 2D drawings and 3D models of parts products and systems prior to manufacturing. The 3D CAD provides for sharing reviewing, simulating there are yeah of course, this some CAD apparent so called

CAD this I like say (Refer Time: 26:47) and all they have the features of simulation to certain extent.

So, it is not only designed, but simulation also is possible with the available configuration or available licenses. Computer Aided Engineering as I have already discussed it is the simulation to test those mechanical properties including force, stress, moment, interaction between parts and such and such things.

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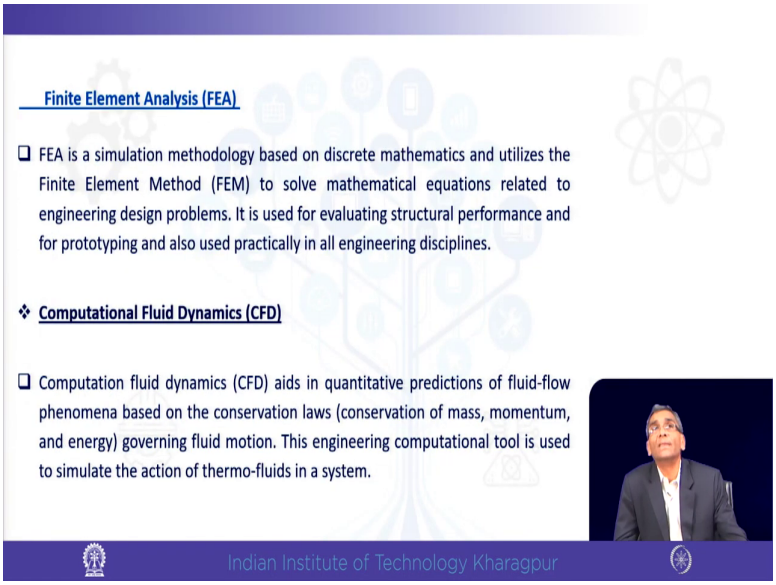

Finite element analysis you can study how the meshing etcetera is done if you intend to study it more, but this is an it is the principle. So, I at the moment I am not going to that there are so many lectures on a finite element analysis or finite element method. Finite element analysis is a simulation methodology which based on discrete mathematics and utilizes the finite element method, to solve mathematical equations related to engineering design problems.

It is used for evaluating structural performance and for prototyping and also used practically for all engineering disciplines, even in fluid thermal thermo fluid application it is the principle. So, the in the that what this discussion brought us to computational fluid dynamics where the conversion of mass momentum and energy is the governing fluid motion.

This engineering computational tool is used to simulate the action on thermo fluid in system. I have given the example of heat exchanger or thermal cooling system etcetera. And also, many other different applications in short time I cannot go on the applications, but if you are interested in a particular software you can always learn that, but and that is always helpful that adds to your skill set and professional proficiency.

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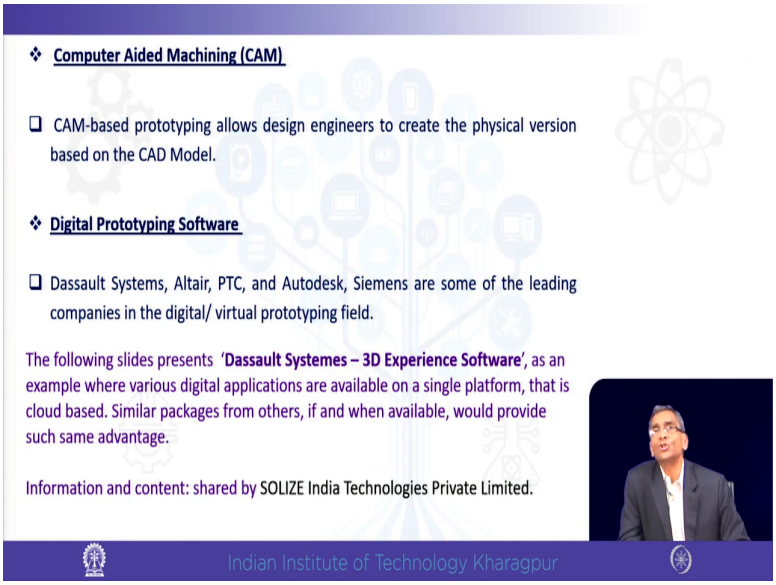

CAM is the software which is used for manufacturing which actually transits the digital model finally, the CAD model which is tested through the analysis CAE and the final model

refine model is put in the system so that it has a interface with the machine. And through that this it can be generated through NC codes and all.

Digital prototyping software there are several software manufacturers like say the Dassault system, Altair, PTC, Autodesk, Siemens are some these are some of the leading manufacturers there are many. But here I would like to present one as an example case nothing more than that where many such software is brought into one platform.

And interestingly it is cloud based and that is why I chose to take up it is not based on any particular bias, but since it is a new one has come in the market. So, I would like to discuss these features of this Dassault Systems 3D Experience Software a bit.

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But I will be very quick because you can go to their website and see, but here I am introducing this to you it has four broad features. One that 3D is for solid works Catia that is the design part V plus R is the virtual manufacturing Delmia Simulia that is the manufacturing software part, then the i to i is the information intelligence and Enovia or PLM that is product lifecycle management purpose.

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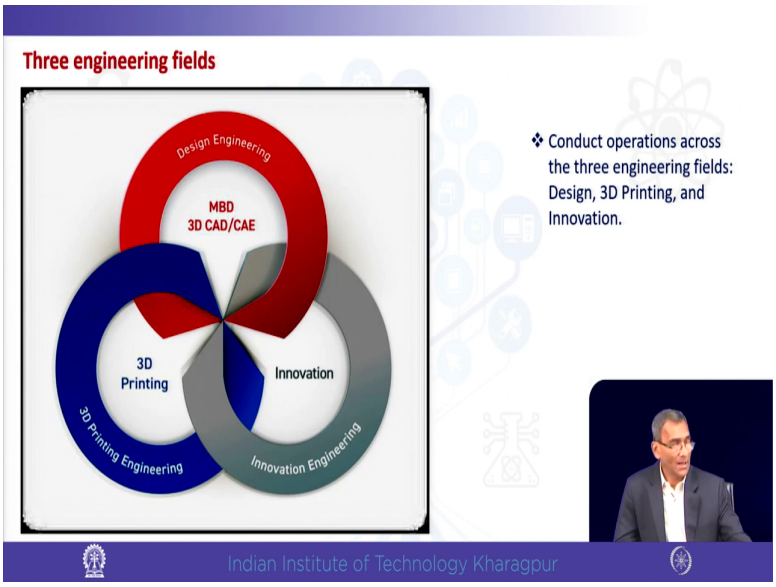

This three engineering field that design engineering, innovation engineering you may recall that in the beginning we discussed innovation engineering in detail and there is a 3D printing engineering. The 3D printing engineering we are living for another discourse. Here we are discussing with this multi-body dynamics 3D CADs, CAE etcetera in the design engineering aspect.

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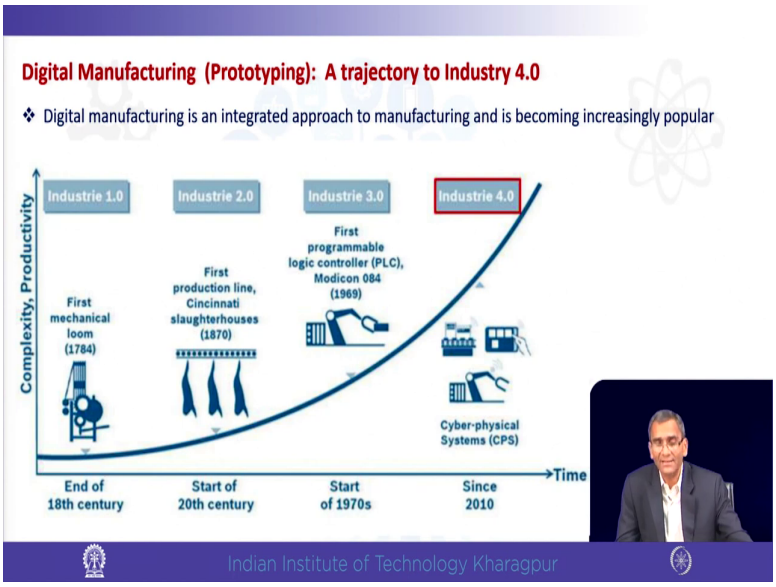

Here I have already discussed, but you can see how the progression from end of 18th century to start of 20th century, to start of 1970s. And now beyond 2010 and now this is the time frame where we have moved from industry 1.0 to 2 .0 to 3.0 now, we are in 4.0 where this digital manufacturing prototype is touching that trajectory or falling on that trajectory. So, that is the integrated approach to manufacturing and that is getting increasing popularity.

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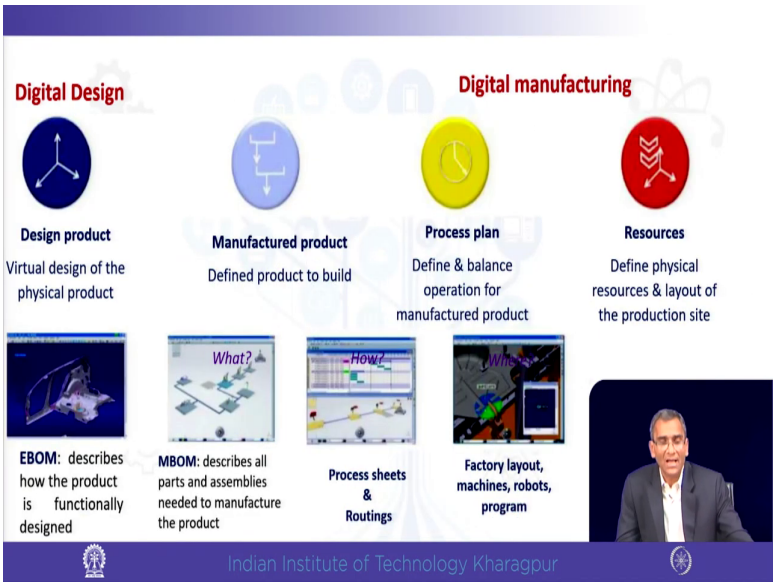

So, there are two aspects I said digital design and digital manufacturing design product that is virtual design of the physical product, manufactured product, defined product to build. Process planning, how the steps will be broken into different process steps, whether it will be first turned and then mailed then drilled then polished then heat treated and then finished polished etcetera etcetera.

Whatever the stages are, maybe it will start with the casting process or forging process. What is the process are that will be the process plan. And then the resources that define physical resources, the layout of the process and the what kind of machine, what is the layout of the machine etcetera.

And then along with it goes the EBOM and MBOM which is described the how the product is functional design and how the assemblies, how the parts are to be fitted in assembly, you

would recall, we discussed the functionality and the allocation of parts into that in the product architecture.

So, we bring back to that. And then subsequently we on that we will have the process sheet, the how the process will go that will be generated from that I said that process planning it would give the process sheet. And then it will give the manufacturing system the machine, the factory layout. And in the factory layout that there handling system, if the robots are there in the handling system and also that would be discussed there these are the features there.

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The ergonomic aspect is important for several reasons this addition access to more than 100 anthropometry variables which can be tested for a product when someone is designing such, be it an automotive a wheelchair or any gadget that people would hold in hand. Practically anything where human interaction with the product happens and that is practically for all,

even a flashlight when someone is holding a flashlight that also needs to be designed ergonomically.

Ergonomic analysis of vision, reach, space, posture, comfort, safety all these can be analyzed through this. Validate posture prediction algorithm for car driver and passengers which is a very exclusive use very commonly and very widely use. So, that is what has been pointed out as a separate bullet. Simulate and validate human task. So, that is the function of this model.

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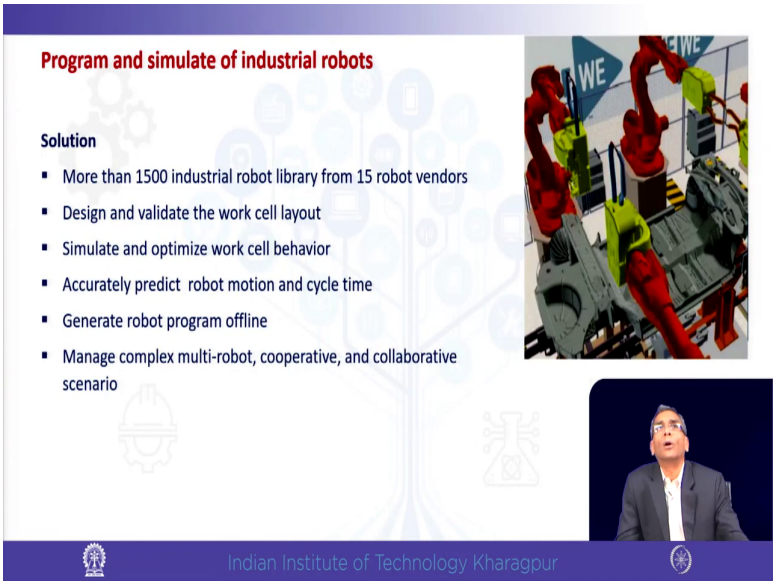

I have already said that it is a complex system. So, for example, a robot how robot would be simulated etcetera. There are say there is a library where one can call out of say 1500 industrial robot which are manufactured by say 15 robot developers or vendors, design and validate the work cell layout, simulate and optimize work cell behavior, accurately predict

robot motion and cycle time, generate robot program offline, manage complex multi robot cooperative and collaborative scenario.

So, this complex system also receives the aid from such software. So, if one learns this software, he or she becomes versatile, really versatile where his employability goes up immensely. So, this is one area, one can actually focus on for career development and career is really quite bright if one stays on and progresses.

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Now, we are towards the end of our discussion. So, we will discuss the closing part of it physical building of it. So, the CAM. So, CAM already you perhaps know that these NC machines and how to program that etcetera you have learned. Here say example of a turn milling system or mill turn system these are different machines.

So, here you can see that complete mill turning and mill turn example case here, combine the two processes, define the NC program in the context of NC machine, machine simulation and integrated with material and removal simulation. So, this is actually to give command and get it done.

So, that we can test that before that fast, collision-free accurate tool paths that it can move. So, everything is planned. So, no late changes will occur reduce product development costs by making concurrent engineering. Because when the designer is doing one can test whether this clashing or collision will happen during manufacturing.

So, there is a huge saving of time that once the design comes then he would explore that is a wasting of time. So, that can be saved. They increase productivity by eliminating traditional data processing delays and the single source of information for all software resources and NC processes.

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So, this is also an important area for this and in that software, these are the packages. Catia, Delmia and Simulia, Enovia and 3DEXCITE, I have already told what they do. And what they do is practically written here it is practically for the I have already discussed what it works and for and it is for the educational purpose mainly which is very very useful for students and faculty members and everyone.

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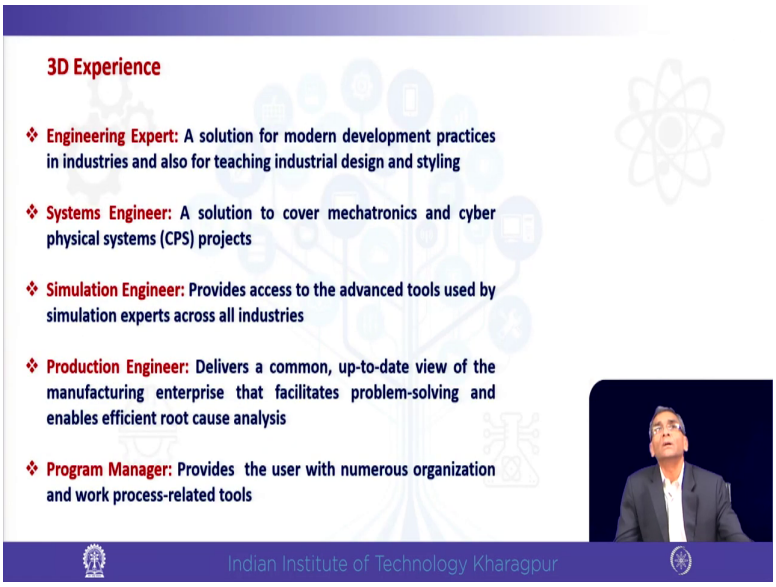

This 3D experience it has got 4, 5 modules engineering expert that is the CAD aspects, systems engineer that is CPA's, simulation engineer that is the simulation part, production engineer that does the CAM part and program manager provides the user with numerous organization and work process related tools, that if you go to that site, you can see all of them.

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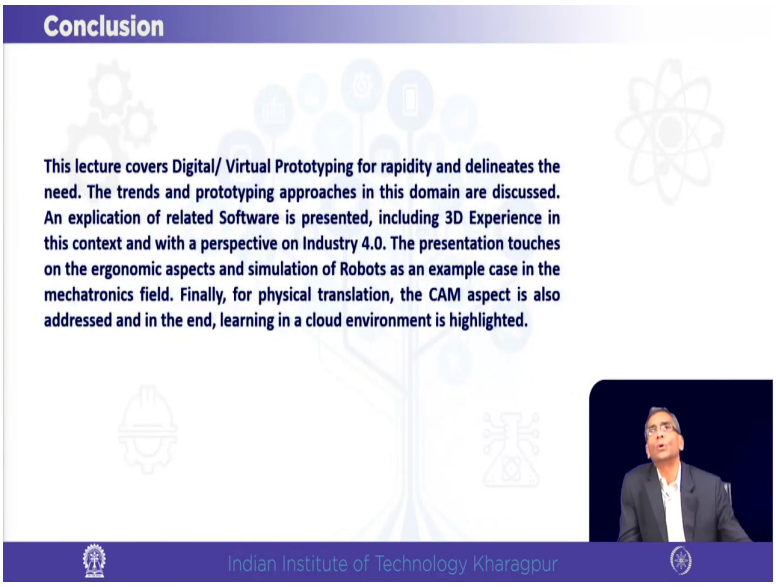

So, this these are the exposures of a software, but trust me as I said in the beginning about the generic approach in design. So, here we will come back to that design not only particular specific package, but then specific package is if versatile can be of great help that is why we included that in our discussion. So, this lecture covers digital virtual prototyping for rapidity and delineates the need, the trends and prototyping approaches in this domain are discussed.

And explication of related software is presented including 3D experience which is now (Refer Time: 38:55) with in this context and with a perspective of industry 4.0. The presentation touches the ergonomic aspects and simulation of robots as an example case in the mechatronic field. Finally, the physical translation, the CAM aspect is also addressed in the end and learning in a cloud environment is also highlighted.

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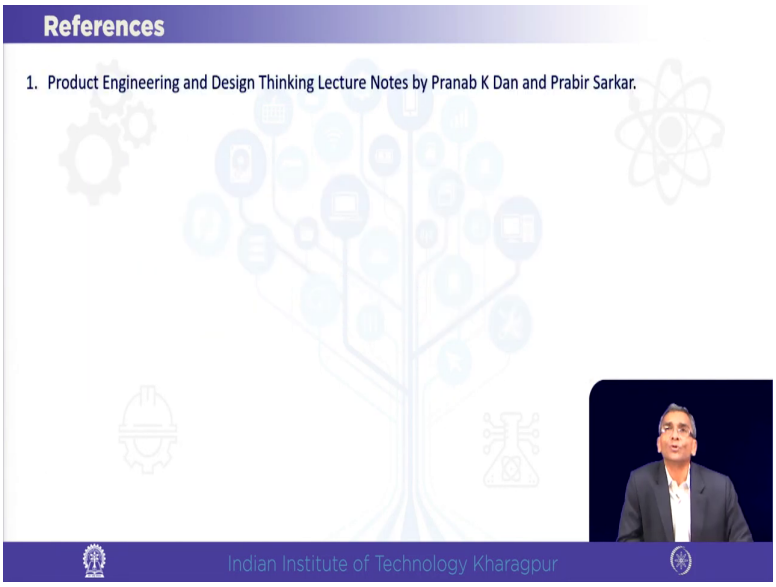

So, we have discussed now. This is the reference you can see and I am sure you would take interest in this. And I am sure that if you study on this subject, it will fetch you huge benefit. And I thank you for attending this session.

Thank you once again.